Roll Splitting for Field Processing of Biomass

Presented to

1987 Annual Meeting of
International Energy Agency
Biomass Energy Agreement
Task III
Harvesting Early Thinnings

By

Dennis T. Curtin
Donald L. Sirois
John A. Sturos

Roll Splitting for Field Processing of Biomass

Prepared by Dennis T. Curtin, Donald L. Sirois, and John A. Sturos[1]

The concept of roll splitting wood originated in 1967 when the Tennessee Valley Authority (TVA) forest products specialists developed a wood fibrator. The objective of that work was to produce raw materials for reconstituted board products. More recently, TVA focused on roll splitting as a field process to accelerate drying of small trees (3-15 cm diameter), much like the process used for conditioning hay.

Recently, TVA's interest in roll splitting was stimulated by its development by the Forest Engineering Research Institute of Canada (FERIC). The interest in this process as a harvesting process stems from several hypothetical advantages and the opportunity to channel funds used for vegetation control to harvest biomass. Cooperative efforts among TVA; the United States Department of Agriculture, Forest Service (FS); and FERIC--along with independent work by other organizations--have confirmed some of the hypotheses. The intent of this paper is to outline the work accomplished to date, not only on roll splitting, but also other components of the harvesting system in which it would play a key role.

Vegetation control consumes tens of millions of dollars annually in the United States. The authors' position is that multiple

---

[1]The authors are, respectively: Harvesting Project Manager, Forest Resources Development Program, TVA, Norris, Tennessee; Engineering Research Project Leader, Southern Forest Experiment Station, U.S. Forest Service, Auburn, Alabama; and Research Mechanical Engineer, North Central Forest Experiment Station, USDA, Forest Service, Houghton, Michigan.

advantages are available through the development of a harvesting system capable of recovering this otherwise unwanted biomass.

Harvesting unwanted vegetation has multiple economic benefits. First, if a capable harvesting system were available, the period between harvests would be extended to allow the vegetation time to mature to the limit of the intended use of the land rather than be limited by the ability of the machinery to control the vegetation. Second, this vegetation could be marketed for fuel rather than being left to enrich the site and increase the rate of undesirable vegetation growth and overall costs. Finally, these lands would become a contributor to economic benefit rather than a drain on local economies.

A Continuous Flow System

Roll splitting is a continuous process lending itself to several continuous flow materials-handling technologies for swath-felling small woody biomass. This approach has many advantages over one-at-a-time technology when handling small stems. Continuous flow of materials, combined with hydrostatic technology, allows optimum allocation of available power between the movement of the machine and processing of materials. As the volume of material requiring processing increases, processing power requirements increase. To achieve this increase, power can be diverted from the vehicle drive train to the processing function, reducing machine speed and feed rate. As the power requirements for processing decreases, power can be returned to the drive train, increasing machine speed and feed rate. Thus, ideal machine and process speeds can be maintained over a wide variety of biomass densities (Mg/ha) and size.

Continuous flow approaches have been applied in several biomass harvesters. But the flow usually ended after stems had been severed. Then the small trees were handled singly or in bunches or bundles. Other continuous flow machines have incorporated chipping or billeting as a secondary process. These options require that the harvester carry an inventory of processed biomass or transfer it directly to a second vehicle. Roll splitting allows several functions to proceed in a continuous flow while allowing these functions to be independent (e.g., drying and baling).

Roll Splitting: What We Have Learned

Through a cooperative agreement between FERIC and TVA, the effects of roll splitting short (approximately 2 meters) bolts were studied. In this early study, manual control of roll pressure and roll spacing maintained a continuous flow of wood through the FERIC splitter. Bolts, split and unsplit, were weighed daily to monitor moisture losses. The weather was hot and dry. Within one week moisture content of the crushed bolts dropped from more than 100 percent (oven-dry basis) to a low of 35 percent (figure 1). This role of moisture loss contributes significantly to the fuel value of biomass.

Fuel consumption data were collected in an effort to estimate roll splitting power requirements. These data proved inconclusive because of the complexity of the hydraulic system and the required intervention of the operator for controlling the process.

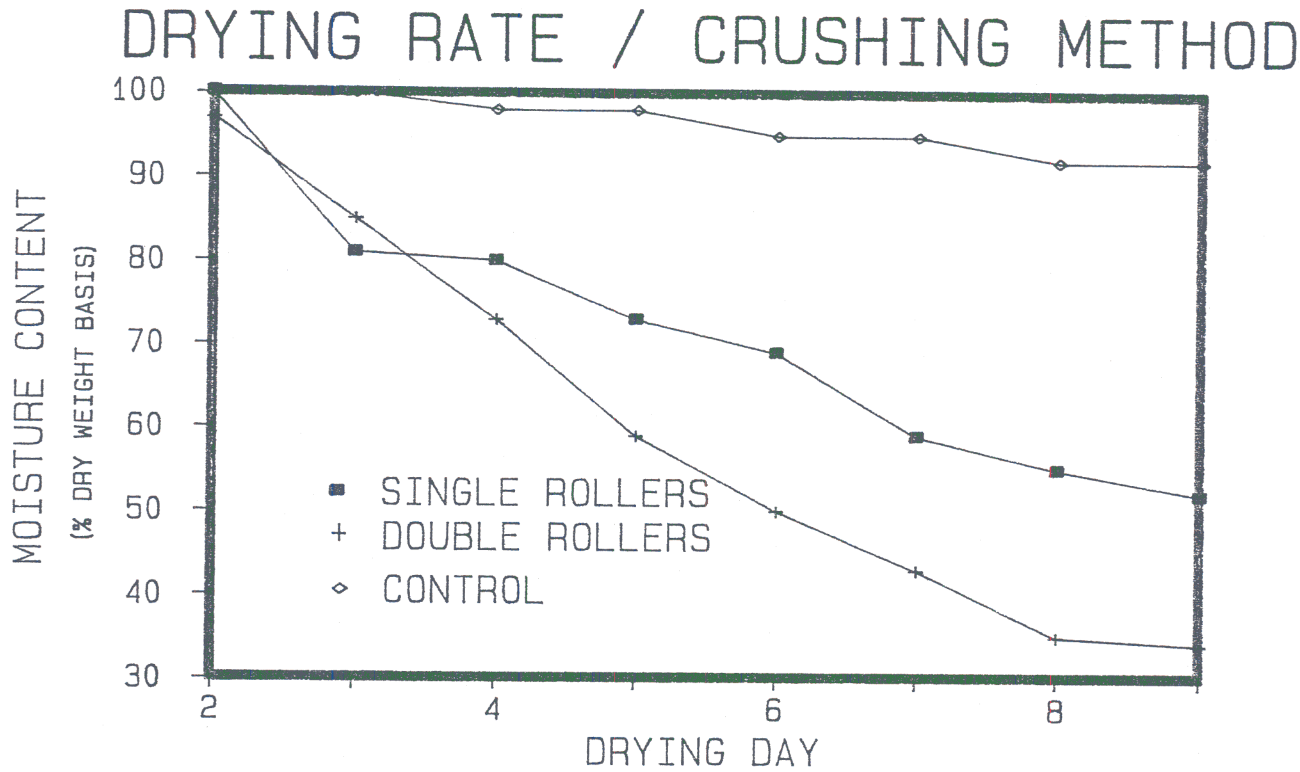

Figure 1. Moisture loss rate of roll split and control bolts, approximately 2 m long.

Following completion of the FERIC/TVA tests, TVA and the FS Southern Forest Engineering Project entered into a cooperative agreement to conduct splitting roll surface tests, to determine parameters to improve the self-feeding of the rolls, establish power requirements, and determine drying rates of whole trees. This comprehensive project was successful in developing criteria for roll splitting small trees up to 17.5 cm in diameter.

The rolls of the FERIC splitter are approximately 31 cm in diameter and 60 cm long. Four rolls are mounted in two vertical sets designated primary and secondary. The first FS task was to determine what combination of roll surface, hydraulic ram pressure (holding the primary rolls together) and roll gap would allow automatic feeding, produce splitting, and feed the stem while the secondary rolls completed the process. Conclusions included the following.

1. The combination of smooth, angled, and serrated bars (designated combo) provided the best surface for feeding and splitting small trees (figure 2).
2. A combination of low hydraulic ram pressure (35 kg/cm^2) and small gap between primary rolls produced the best feeding and holding characteristics (figure 3).
3. Secondary roll surface of simple bars (1.0 cm wide and 0.5 cm high) welded 20 cm apart provided adequate feeding and crushing.
4. Splitting, not crushing, produced the greatest increase in drying rate.
5. The total power required to drive both sets of rolls and produce satisfactory splitting of trees up to 18 cm in diameter at a rate of 15 m per minute was less than 11 kW (figure 4).

The whole-tree drying tests were conducted under more realistic field conditions than were the bolt drying tests discussed earlier. Whole trees were roll split under the self-feeding parameters and roll surface conditions described above. Both treated and untreated trees of three genera (<u>Pinus</u>, <u>Liquidanbar</u>, and <u>Quercus</u>) were allowed to dry on the ground for 3 months. During that time each tree was weighed once a week. Figure 5 reflects the results of the <u>pinus</u> tests, which was similar to the other genera. Note the erratic moisture content behavior of the treated stems and how it was affected by rainfall.

These results, although less conclusive than the bolt tests results, reflect the combination of weather and ground contact conditions crushed trees will likely experience.

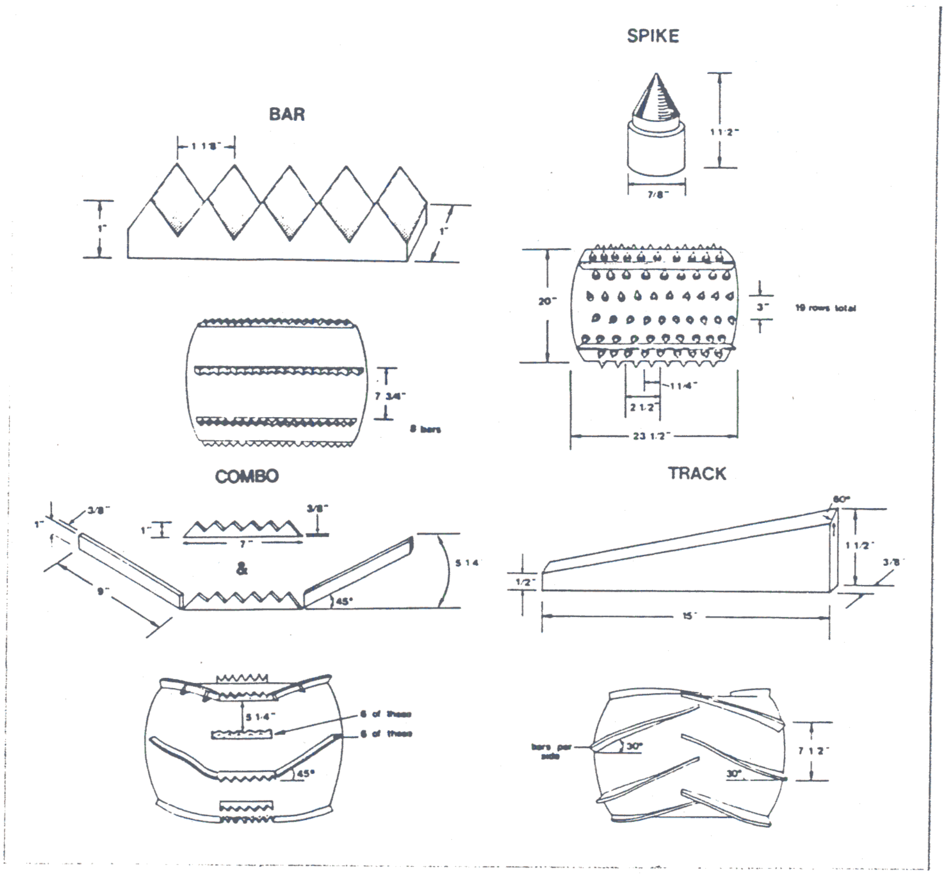

Figure 2. Roll surface configurations tested by the USDA, FS.

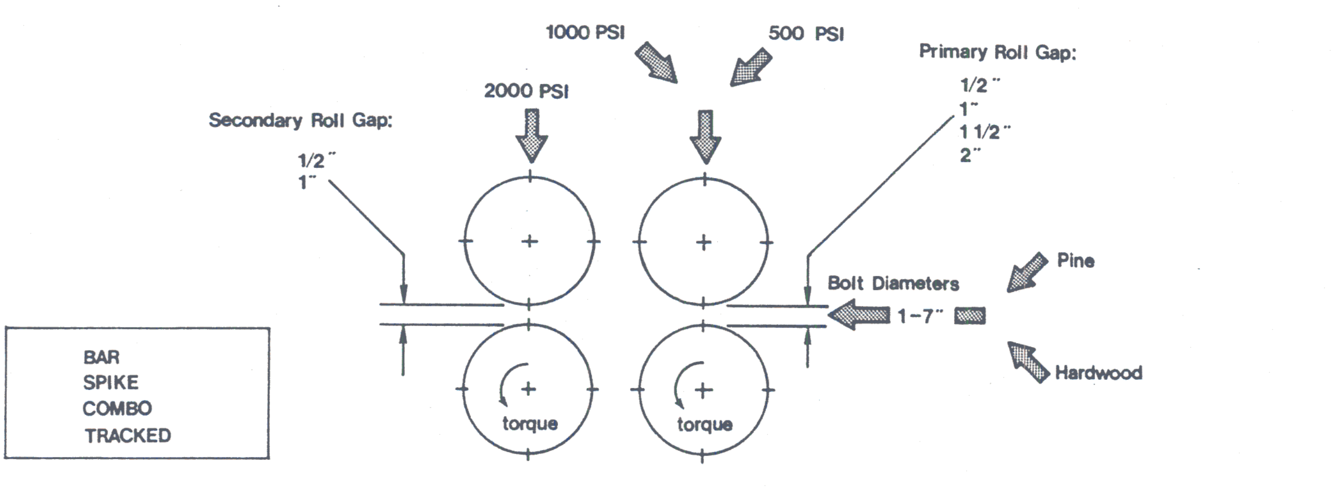

Figure 3. Roll splitter gap and pressure trials.

1396R

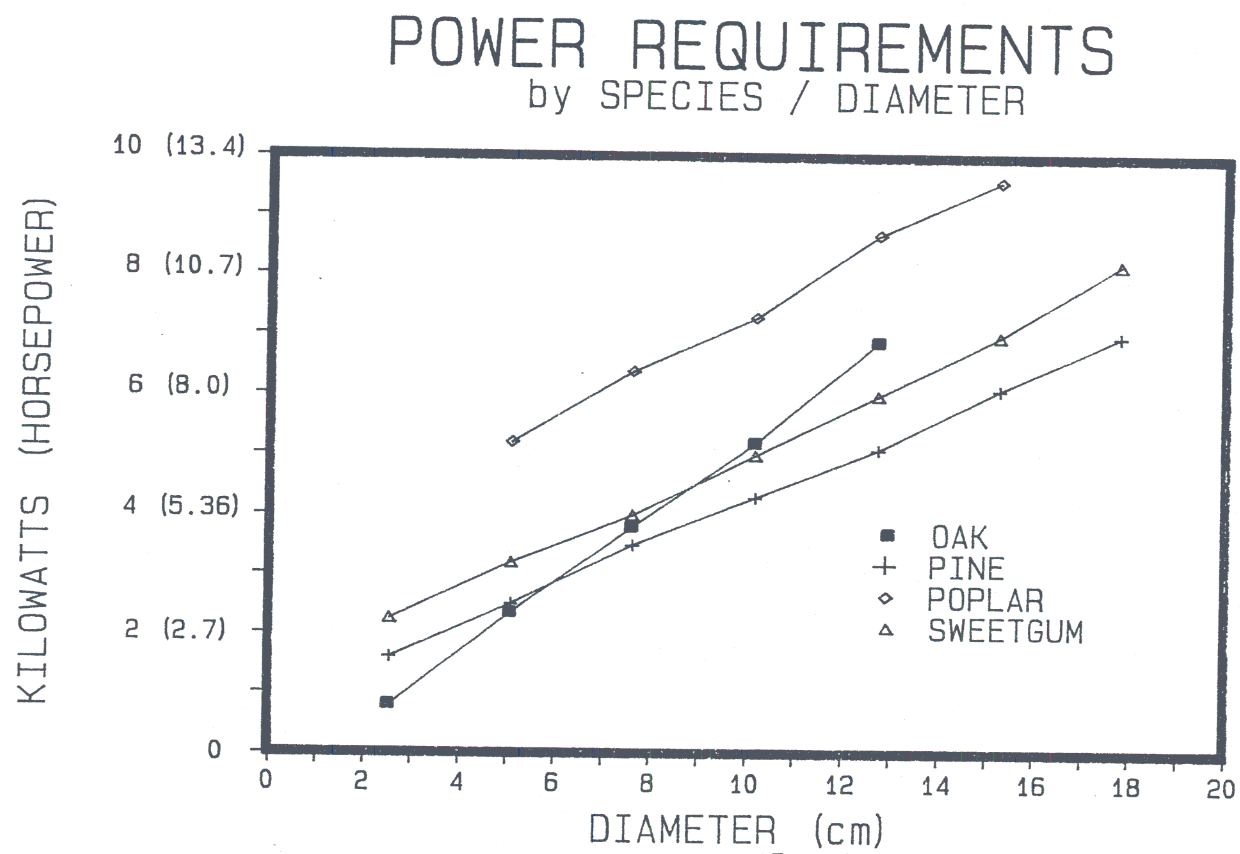

Figure 4. Total power (kw) versus diameter for roll splitting.

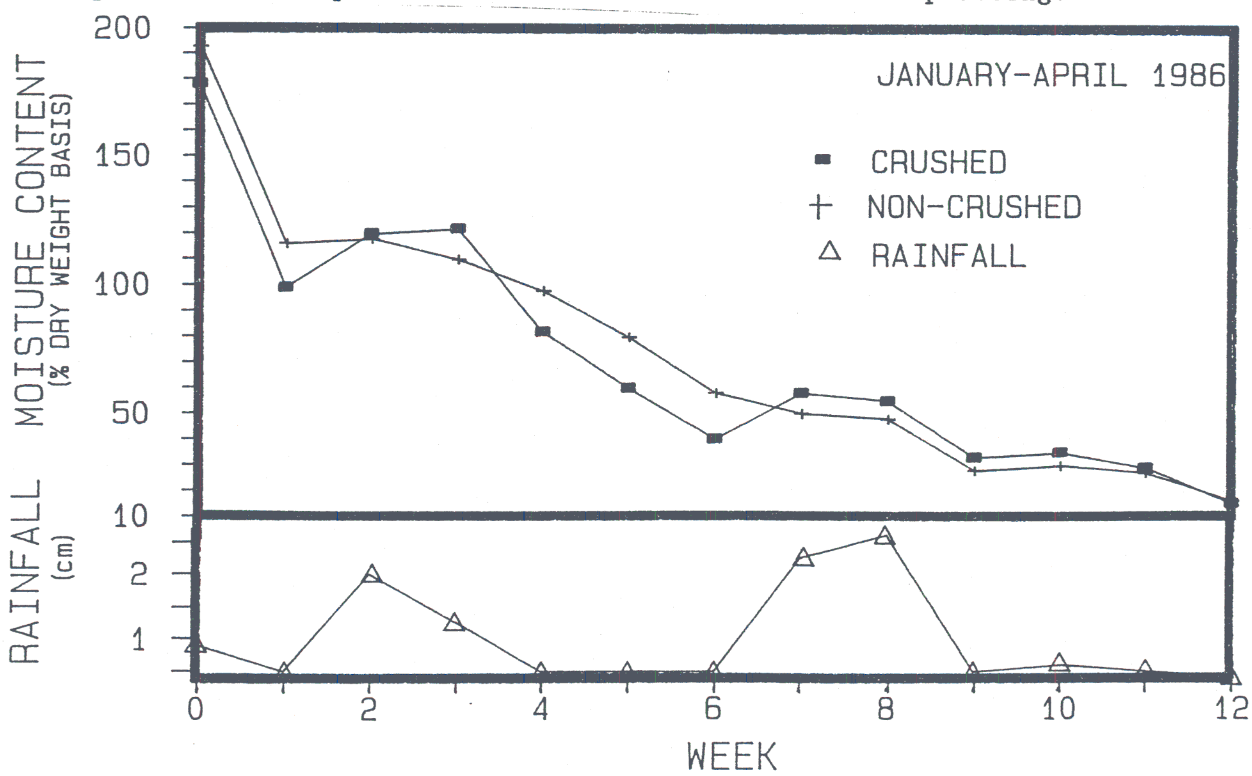

Figure 5. Drying rates of whole pine trees and rainfall.

1396R

These findings support continued explorations into other elements of a continuous flow, low-power harvesting system. Questions such as "What severing mechanisms would operate in front of splitting rolls?" and "What gathering mechanisms could collect the processed biomass?" remained.

Other System Components

Coincidentally, and independently of TVA and FS studies, Omark Industries, Inc.[2], and GK Machine Shop, Inc., of Portland, Oregon, tested a chain saw severing mechanism to harvest dense stands of woody biomass. Their tests show that a horizontal bar, located above and in front of a horizontal chain saw bar, established tension in the standing stems. As the tensioned stems are severed, the ends jump over the bar as the tension is released. This phenomenon continued as a long row of this dense planting was cut (figure 6). This finding suggests that a feed mechanism located directly behind the cutting chain can control and guide the severed stems into a roll splitting mechanism. Other methods such as disk saws or rotary cutters may also be suitable. Testing of this combination has not been carried out.

The next obstacle in developing a harvesting system based on roll splitting is a recovery system. Rather than develop a new method to pick up small trees, we looked for opportunities to use available baling systems. The Claas Company[2], which produces a round hay baler based on

---

[2]The use of company and trade names is for reader association and identification only and does not constitute or imply endorsement by TVA or the USDA, Forest Service.

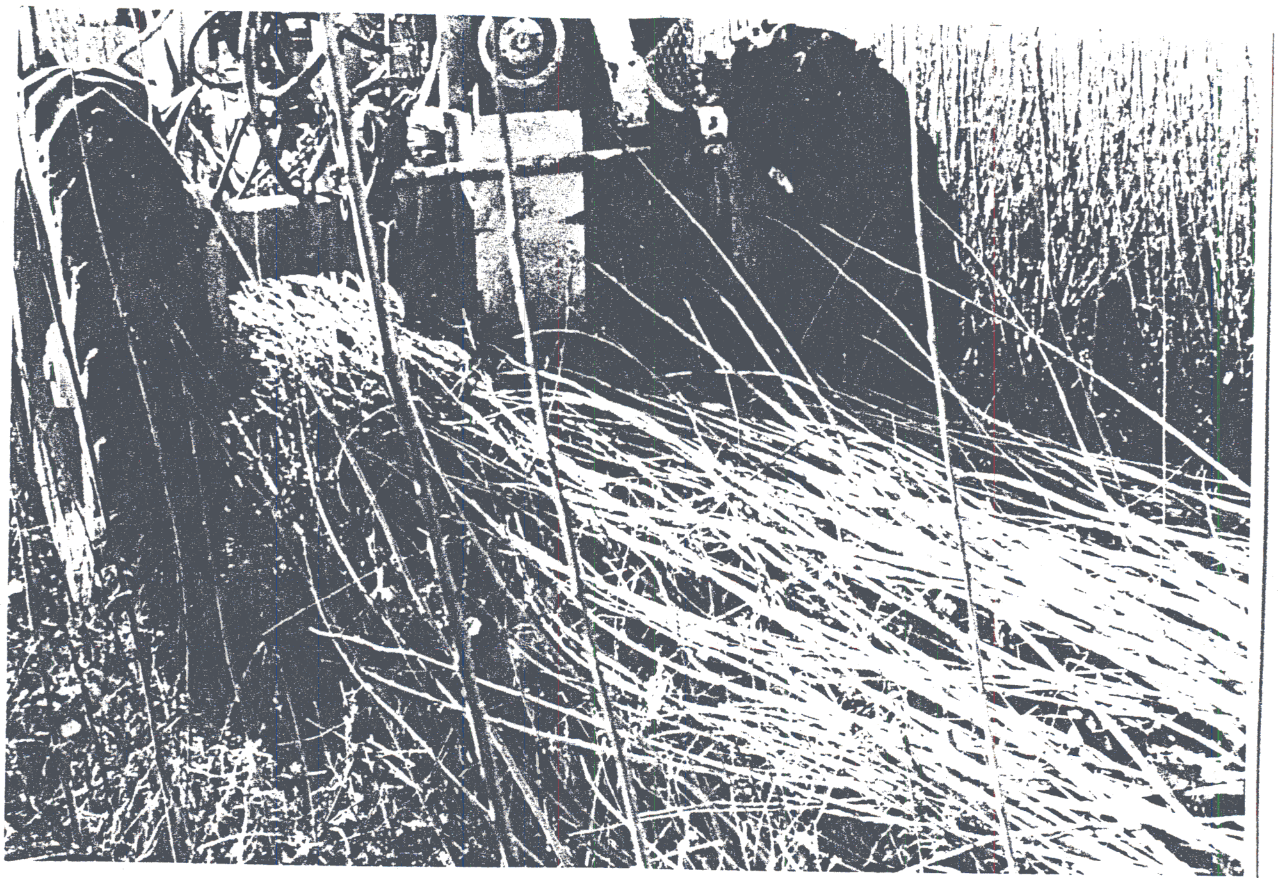

Figure 6. Swath-cut woody biomass behind Omark/GK Machine Shop high-speed saw.

metal rolls rather than belts, was identified as a potential cooperator (figure 7). In a coordinated effort, the FS roll split more than 500 kg of small trees using the FERIC roll splitter. These trees were allowed to dry for several weeks.

The feed mechanism on the unmodified Claas baler was unsatisfactory for feeding trees into the bale chamber and forming a central core for the bale. Since the Claas baler depends on the tumbling core to provide the friction between the incoming biomass and the rolls, no feeding of stems was accomplished until a core was established. However, once the core was formed (by hand feeding short lengths of crushed tops and stems) and it began tumbling, feeding became <u>very aggressive</u>. At this stage, the Claas baler was capable of drawing in

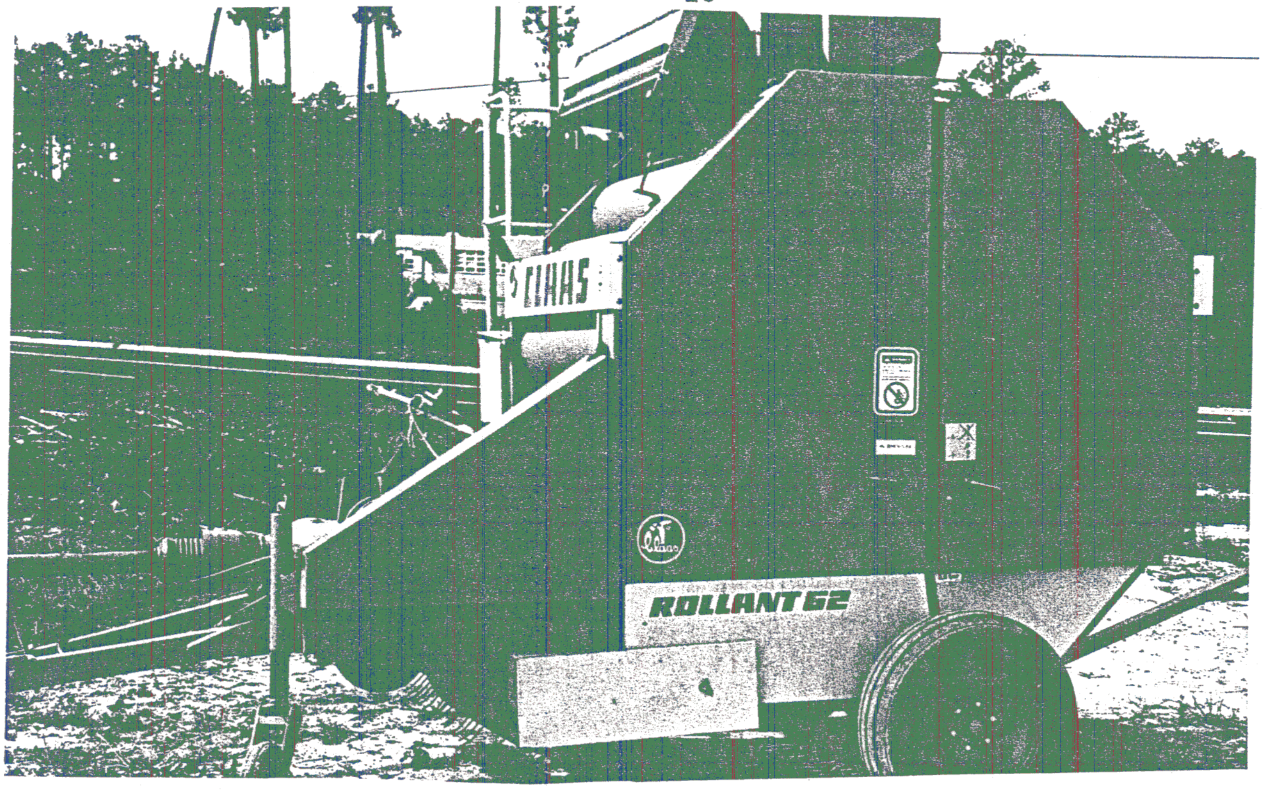

Figure 7. The Claas Rollant 62 baler.

whole trees and baling them. Up to 7.5 cm diameter stems were drawn into the baler at a rate of approximately 2.5 meters per second.

After the core was formed, small trees were laid on the ground to simulate a row of trees severed using a mechanism similar to the one developed by Omark/GK Machine. These trees were "shingled" with the top of each tree resting on the base, or midpoint, of the tree that followed it in the row (much like a line of fallen dominoes). As the baler approached the row from the base of the trees, the hay spring tines head failed to pick up the trees. When the opposite approach was tried, gathering and tops first feeding was very successful; and nearly 100 percent of the trees were picked up.

When the baling chamber was full, a Rolleter[2], high-speed net wrapping system, integral to the baler, was used to hold the baled biomass together. These tests were concluded when all the split trees and some other small, split trees had been baled. This constituted one full bale and one partial bale. The full bale weighed 325 kg and had an average moisture content of 38 percent (O.D.). This converts to approximately 235 kg oven-dry and a bulk density of 116 kg/M^3 (figure 8).

Two specific problems remain. First a more aggressive feed mechanism is necessary to feed the baling chamber and establish the bale core. One option would be to include a crushing function as the feed mechanism. This would make feeding more aggressive but would also provide an opportunity to begin curling the trees if two longer bottom rolls and a smaller top roll were used. This configuration of crushing/feeding rolls would also help solve the second problem--that of low-bulk densities for the bale. A possibility for improving the baling density may be to develop an expanding baling chamber. This may help establish a more dense core and bale.

While efforts were being made to reduce the two bales of woody biomass to particle size more in line with available handling and burning systems, the bales were left out in the weather. During this time, November 1986 through April 1987, the moisture content of the bales declined to 14 percent. This ability to dry biomass after baling offers new opportunities for integrating, severing, splitting, and baling into a single function. However, as more dense bales are produced, the ability of the baled biomass to dry will be reduced.

The baled biomass presented a final problem--how to convert a bale of woody biomass to a usable fuel particle. Taking the same approach of using available technology, a grinder (figure 9) was selected. Tub grinders are commonly used in the United States to reduce large bales of hay and distribute hay into feeding troughs.

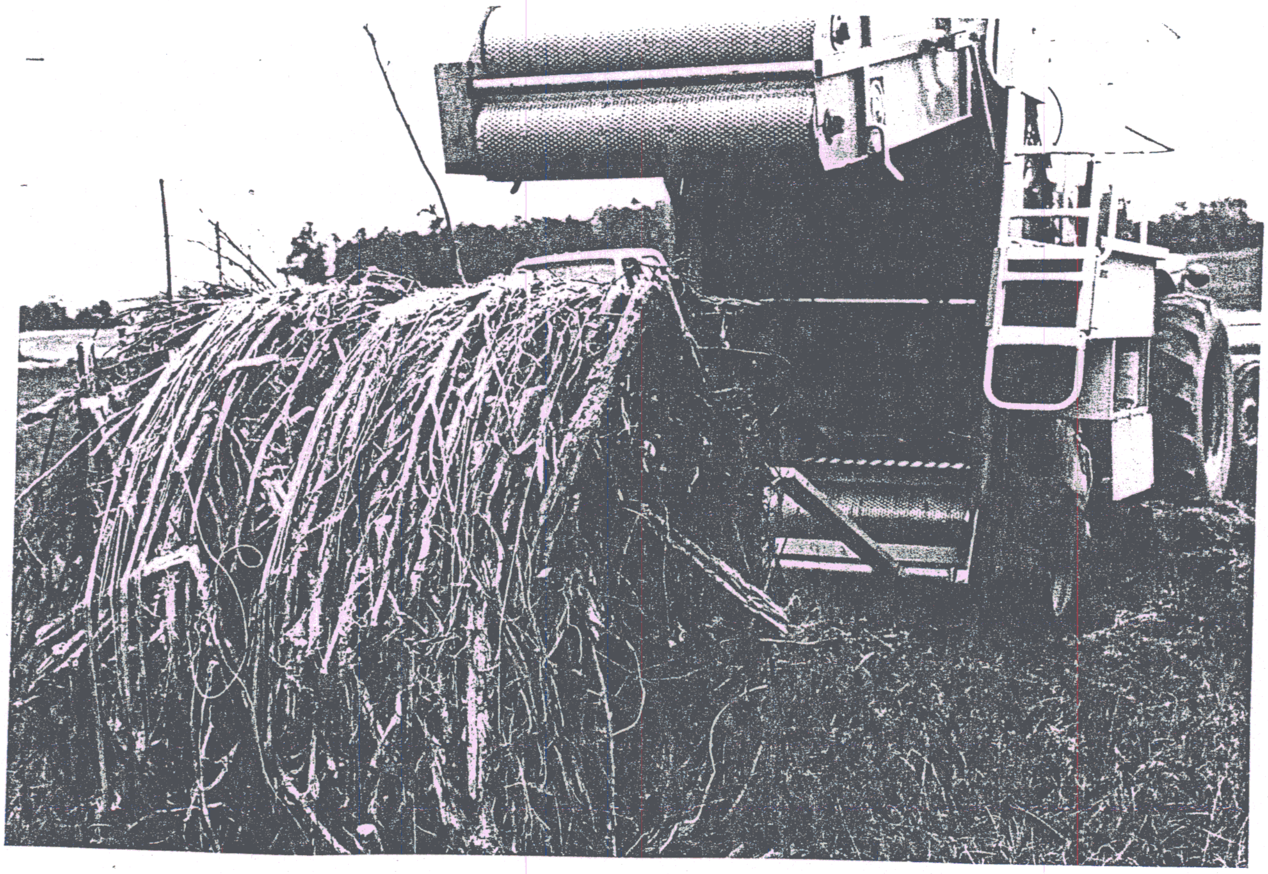

Figure 8. A bale of whole trees.

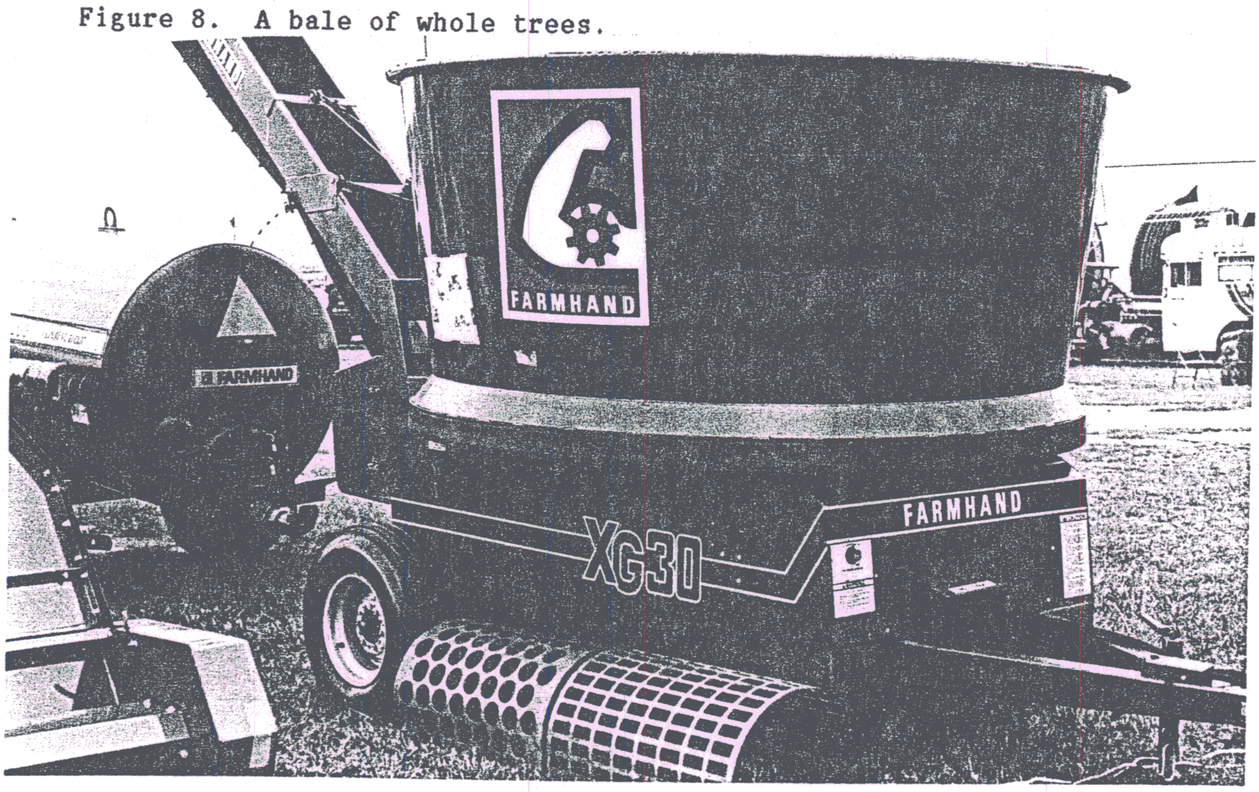

Figure 9. The tub grinder similar to the one used to reduce the baled trees.

1396R

Each bale was loaded into the tub grinder using a farm tractor equipped with a set of forks. The grinder was powered by an agricultural tractor producing approximately 72 kW at the Power Take Off (PTO) unit. The tub grinder/tractor combination successfully reduced the dry bales at a rate of approximately 4.5 mg per productive machine hour.

The particle size produced by the tub grinder is dictated by the size of the holes in the screen in the bottom of the small hammermill, which is the actual processing element in the tub grinder (figure 8).

For this test the screen holes were 3 cm by 10 cm. A 50-kg sample of these particles was sent to the Engineering Project of the FS North Central Forest Experiment Station in Houghton, Michigan. The sample was sorted using a Williams Pulp Chip Classifier screen (figure 10) with five screen sizes ranging from 4.8 to 28.6 cm. Figure 11 illustrates the results of this analysis. The particles resemble pinchips in many respects. Although the processing substantially increased the bulk density of the biomass, the particles produced could result in major bridging problems. For this reason, we do not recommend this process unless the material is going directly from the tub grinder into a boiler--unless special handling equipment is used. To inventory biomass in this form without providing for possible severe binding and bridging problems would be counterproductive. The removal of this material from a truck could be a major problem.

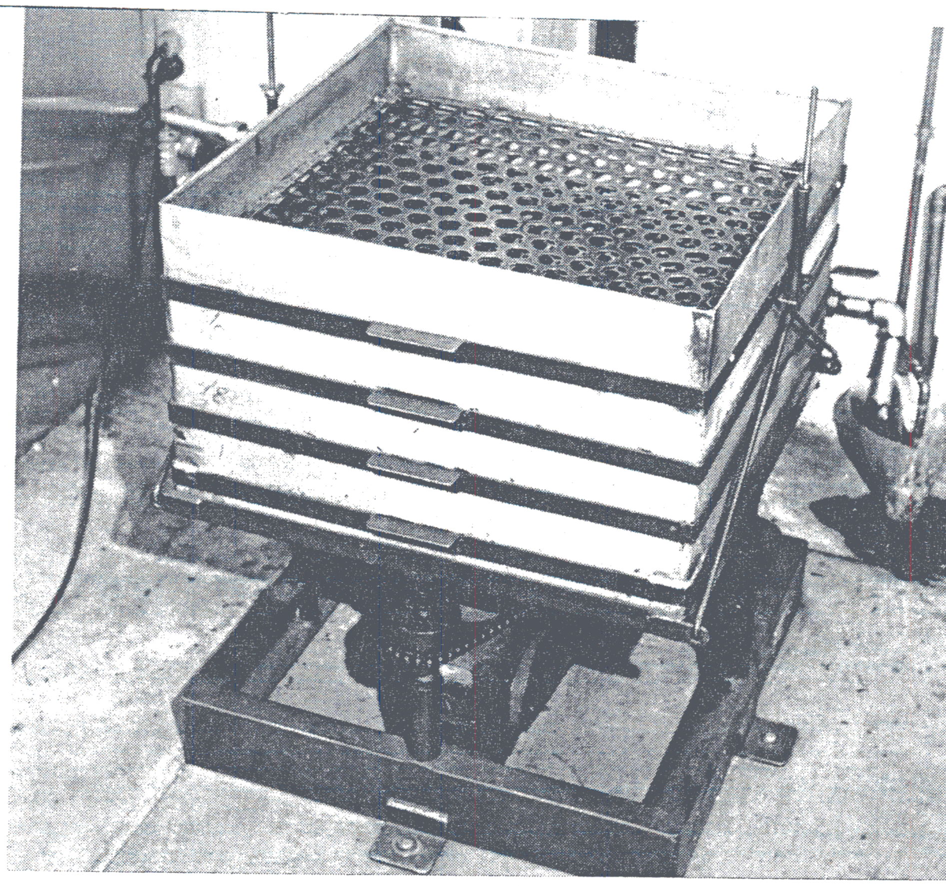

Figure 10. The Williams Pulp Chip Classifier used to classify particles produced by grinding baled trees.

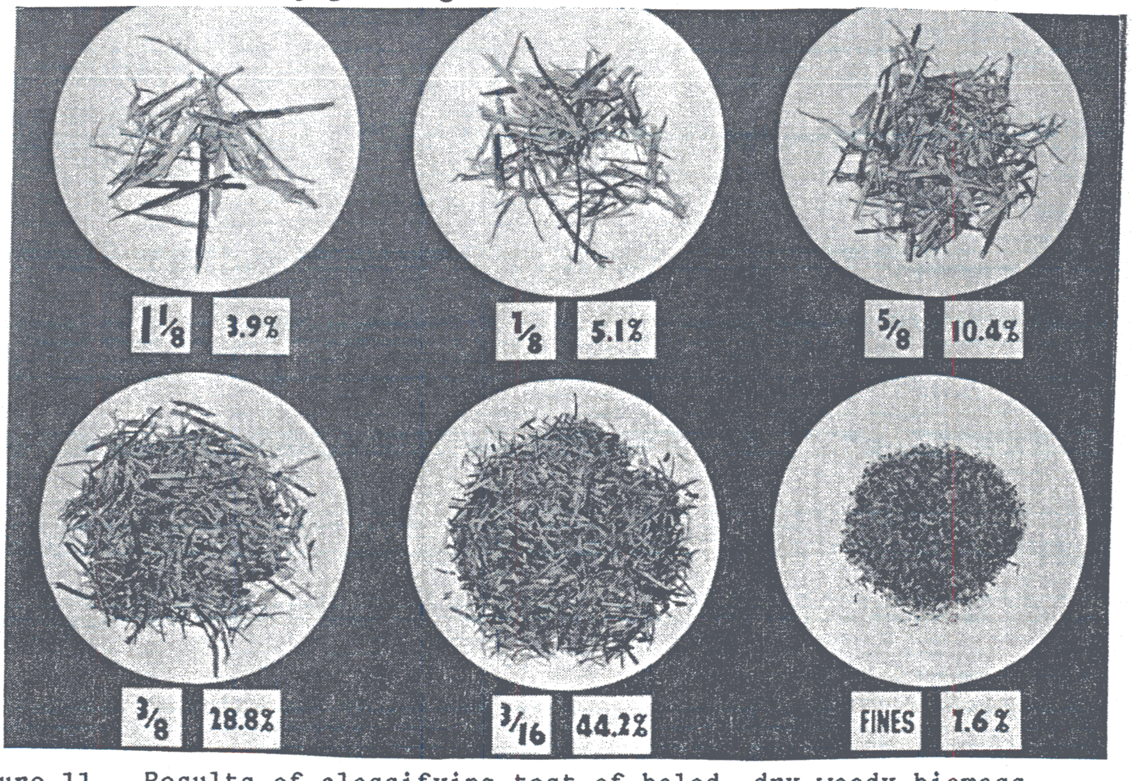

Figure 11. Results of classifying test of baled, dry woody biomass processed with a tub grinder.

Conclusions and Recommendations

Roll splitting offers the possibility of low-energy consuming opportunities for harvesting and processing small woody biomass. Severing, feeding, and splitting may require less than 40 kW. However, the movement of the prime mover across terrain will require additional power.

Baling was accomplished using a hay baler that used steel cylinders to encompass the wood and produce 325 kg bales. This function was accomplished using a tractor, producing approximately 45 kW at the PTO. Reduction of the bales was accomplished using a tub grinder powered by an agricultural tractor, producing 72 kW at the PTO.

All the technologies are available to assemble a harvesting system based on a tractor in the 75 kW size class. What remains is a project to assemble the components into a working system.

Bibliography

Ashmore, Colin. Roll Splitting of Biomass. In: Proceedings, 13th Annual Mountain Lake Vegetation Management Council, Inc.; 1984 September 16-18; Fredricksburg, VA. Blacksburg, VA: Southern Printing; 1984: 16-18.

Ashmore, Colin, Donald L. Sirois, and Bryce J. Stokes. Evaluation of Roll Designs for a Roll Crusher/splitter Biomass Harvester: Test Bench Results. In: Proceedings of the 1986 Southern Forest Biomass Workshop; 1986 June 16-19; Knoxville, TN. Norris, TN: Tennessee Valley Authority; 1986: 113-119.

Barnett, Paul E., Donald L. Sirois, and Colin Ashmore. Reduction of Biomass Moisture by Crushing/splitting - A Concept. In: Rockwood, Donald L., ed. Proceedings of the 1985 Southern Forest Biomass Workshop; 1985 June 11-14; Gainesville, FL. Gainesville, FL: Institute of Food and Agricultural Sciences, University of Florida; 1986: 13-16.

Barnett, Paul E. and Donald L. Sirois. Roll Splitting as an Alternative Intermediate Process for Wood Fuel. In: Forest Energy Newsletter, No. 4; October; Forest Energy Secretariat, SLU Garpenberg, Sweden; 1985.

Sirois, Donald L. and Colin Ashmore. Design Considerations for a Roll Crusher/splitter for Woody Biomass. In: Fourth Southern Biomass Energy Research Conference; 1986 October 7-9; Athens, GA. Athens, GA: University of Georgia; 1986: 33.

Woodfin, Samuel L. and Bryce J. Stokes. Conventional Round Baler Evaluated for Biomass Recovery. March/April; Biologue, Vol. 4, No. 2; 1987.